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Analysis of Energy Consumption in Pineapple Cultivation in Malaysia: A Case Study

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ABSTRACT

Pineapple (*Ananas Comosus)*, which has been identified as high-value non-seasonal tropic fruit, is one of the top five fruits in Malaysia that shows a promising demand in the local and export markets. The current study was conducted to analyse the efficiency energy inputs used in every activity involved in the process of pineapple production. The study also aimed to contribute in initiating a database for energy used in producing pineapples in Malaysia, which would hopefully become a guideline for applications in related policies in pineapple plantations. Data were collected based on direct field observations at a pineapple plantation under the management of Koperasi Serbaguna Anak-Anak Selangor Bhd. (KOSAS Bhd.) at Kg. Kundang in Selangor, Malaysia. Oral interviews were also carried out to gather any relevant information. The highest energy input used in pineapple production is fertiliser, contributing to 45.65% from the total energy equivalents used in the production. Fuel is the second highest energy source with a segment of 20.21% of the total energy, followed by planting material, agrochemicals, human labour and machine at 17.33%, 12.76%, 3.34 % and 0.69%, respectively. The ratio of energy output/inputs in pineapple production in the study area was 3.56. Conclusively, it means the energy input is effectively used in the pineapple production in the study area since the energy output/inputs ratio is greater than 1. Involvement of machinery in the pineapple cultivation practices in Malaysia is recommended since it reduces human drudgery and optimises farm's capability to do work more efficiently and also to offset the labour shortage problem.

Keywords: Pineapple plantation, energy consumption, energy efficiency, sustainable agriculture, mechanisation

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INTRODUCTION

In Malaysia, pineapple *(Ananas Comosus)*, which has been identified as a high-value non-seasonal tropic fruit, is one of the top five fruits that shows a promising demand in the local and export markets. The focus in pineapple cultivation is to increase its production on mineral and peat soils, mechanise pineapple production and add value to the fruit before it reaches the market. There is a growing interest among growers by planting a fresh fruit variety as it seems to have better demand in both domestic and foreign markets. The rising star for the pineapples is the MD2 variety, a hybrid variety that originates from Hawaii.

Statistically, about 90% of the pineapples in Malaysia are cultivated on peat soil, while the rest are planted on mineral soil (Chan, 2000). Based on the statistics by the Malaysian Pineapple Industry Board (2012) shown in Table 1, the pineapple production fluctuated between 2008 and 2010. At that time, the pineapple production from pineapple small holders increased, while the production from the plantations decreased by years.

Table 1
Production of pineapples (in metric tons)

Year	Small holder	Portion of total production (%)	Plantation	Portion of total production (%)	Total
2007	12,109	17.40	57,498	82.60	69,607
2008	98,895	63.35	57,216	36.65	156,111
2009	59,164	51.47	55,794	48.53	114,958
2010	79,158	62.13	48,257	37.87	127,415

Source: MPIB (2012)

Nowadays, the agricultural sector relies heavily on the input from the fossil fuels to produce outputs. It is a well-known fact that a high consumption of this source of input results in negative environmental effects through the release of CO_2 and other greenhouse gases that leads to global warming. Ironically, even though we are aware of these bad effects, the continuous use of fossil based fuels is inevitable in modern farming practices to increase yields and reduce the risks of production loss. This is due to the intensification of agricultural practices to ensure food security for the growing human population. Mechanisation, agrochemicals, fertilisers and herbicides are among farm inputs produced by fossil fuel sources. Thus, searching for agricultural methods that require lesser energy input with higher energy productivity has become one of the important issues today (Refsgaard, 1998). As human activities are closely related to energy use and the cost it incurs, energy analysis can be a good tool for providing an overview of the energy used for an activity. Effective energy use in agriculture is one of the conditions for sustainable agricultural production as it leads to financial saving, better fossil fuel preservation and lesser air pollution (Pimentel & Patzek, 2005).

Many relevant studies have been done so far; however, these works generally focused on world's main crops production such as wheat, rice, soybean, cotton and sugarcane to improve the energy output–input analyses and investigate their relationships (Ricaud, 1980; Mandal et al., 2002; Safa & Tabatabaeefarz, 2002; Bockari et al., 2005; Nuray, 2009). Yet, in Malaysia, there is not much work done to investigate energy input in crop cultivation. Meanwhile, several related studies reported by Bockari et al. (2005) and Pebrian et al. (2014) focused on certain main crops such as rice and oil palm cultivations. A similar study on energy consumption in pineapple cultivation in Hawaii was reported by Duke (1983). However, the available data from the previous research could not be utilised in analysing energy consumption for pineapple production in Malaysia because of the differences in the cropping system, soil characteristics and nature of works. Thus, energy input/output analyses are urgently needed to determine the energy efficiency and energy pattern, as well as their distribution in pineapple plantations in Malaysia.

The study aimed to analyse energy input/output used in the pineapple production in Malaysia. The distribution of energy input used in the production of pineapple, energy efficiency and energy pattern were also studied. The study could contribute to initiation of a database for energy consumption in pineapple production that can serve as a guideline for applications within related strategic farm management policies.

MATERIAL AND METHODS

The data of this study were obtained through field observations carried out from April to July 2012 at a pineapple plantation under the management of Koperasi Serbaguna Anak-Anak Selangor Bhd. (KOSAS Bhd.) located in Kg. Kundang in Selangor, Malaysia. With a planting area of 300 acres, this plantation is among the largest pineapple plantations in Selangor and it can be considered as a representative of a typical pineapple plantation in Malaysia. The type of soil in the study area is peat soil with a good natural water supply system (ditch). Thus, with this condition, irrigation activity was excluded in the data collection. The data were collected for all the field operations involved in pineapple production process in the field such as land preparation, planting, fertilising, weeding, spraying and harvesting.

Description of field operations

The description of field operations involved in pineapple production process at the Koperasi Serbaguna Anak-Anak Selangor Bhd. (KOSAS Bhd.) plantation is as follows:

Land preparation. Since the type of soil in this area is peat soil with a good natural water supply system, thus land preparation is started by constructing drainage to lower the water level for the requirement of pineapple cultivation. A ditcher was used to make ditches to remove excessive water for the plantation areas. The ditches were also cleared from weeds and any hindrance material once every three months. In replanting areas, a 37 kW tractor-mounted sprayer, a pair of *2000 litres herbicide* tanks was used to kill the crop residues left in the areas before planting begins. After a week, slashing and burning were employed to clear and clean the entire areas from any debris and crop residues so that the areas are ready to be planted with pineapples.

Planting. This plantation employs a high density planting system with a total of 22000 pineapples planted per acre with planting distances of 30 cm x 60 cm. Planting was started with lining task. Tied wood is used to make lines in planting rows. A special tool made from wood, which is locally known as “Tugal”, is utilised to dig planting holes. The workers used the "Tugal" wood dig planting holes at a depth of 10-15 cm while walking in the planting areas. Prior to planting, all the planting materials were delivered to a location near the planting areas using a 37 kW tractor-mounted trailer.

Fertilising. There two types of fertiliser, namely, foliar fertiliser and granular fertiliser, applied in this plantation. The foliar fertiliser is chemical fertilisers such as ferrous sulphate, zinc sulphate, hydrate lime, copper sulphate and urea that are mixed with water. They were applied to the planting areas when the pineapples are 6 and 18 weeks old. Meanwhile, the granular is a compound fertiliser or NPK fertiliser utilised to the planting areas when the pineapples are 12, 14 and 34 weeks old. The granular fertiliser was distributed manually by the workers using their hands, while the foliar fertiliser was spread to the planting areas through the use of a 37 kW tractor-mounted high pressure sprayer. The sprayer tank can accommodate 2000 litres of liquid solution at a time.

Spraying hormone. Spraying hormone was performed when pineapples are 40 weeks old for the purpose of flower induction. Similar to the fertilising operation, this plantation also uses a 37 kW tractor-mounted high pressure sprayer with the tank capacity of 2000 litres to spray hormone to targeted crops.

Weeding. In this plantation, weeding was carried out every month until the pineapples are at age 40 weeks. The weeding was done manually using simple hand tools to remove weeds off the ground. This operation is considered as a laborious task because the planting distances are too narrow.

Crop Protection. A "cap" was used to protect the pineapple's crown from sunburn. The cap was made from high density paper and fitted on crop when it has formed fruit and crown. Like weeding, this operation was also a painstaking job and undertaken manually.

Harvesting. The harvesting operation is accomplished manually. The worker brings along a basket to harvest ripe fruits by using a sharp machete while walking in the harvesting areas. The basket was made from bamboo material and utilised to store the harvested fruits during the harvesting operation. When the basket is fully loaded, the worker moves while carrying along the basket to the temporary collecting point at the main road side to unload the harvested fruits. A 37 kW tractor-mounted trailer waiting at the temporary collection point was employed to transport the harvested fruits to the packing house.

These operations were observed for 12 (twelve) experimental plots based on an acreage basis. Oral interviews were also conducted with the plantation manager and workers to gather all the relevant information.

Data Analysis

Energy analysis was performed based on the above field operations, as well as on the direct and indirect energy sources involved in the pineapple production process. Firstly, measurements of inputs such agrochemicals (kg), human labour (h), machinery (h), fertilisers (kg), fuel (L) and seeds (kg) used in the production of pineapple were specified in order to calculate energy equivalence in the study. For the operation using a self-propelled machine, fuel consumption was measured by filling the machine's fuel tank twice, before and after performing each operation based on Alcock (1996). All of the experimental plots were managed with the same field practices including land clearing and planting method, amount of fertiliser and agrochemicals used, crop protection and harvesting system in order to reduce the significance of differential on crop yield.

Fuel consumption for tractor was estimated based on the formula from ASABE Standards (2009), as follows:

The average diesel consumption (l/h) = rated PTO power (kW) X 0.305 literkWh^{-1}. (1)

Energy was calculated according to the obtained input, multiplied with the coefficient of energy equivalent from the previous research literature, as indicated in Table 2. The unit of the results was in megaJoule (MJ) per hectare term. The energy contributed by machine can be calculated according to Moerschner and Gerowitt (2000), as follows:

Energy of machinery = [weight of machine (kg) X coefficient of energy for machine (MJkg^{-1}) X working hour (hha^{-1}) X number of application] / wear-outlife of machinery (2)

Using the summation of energy equivalences of all inputs in MJ terms, the total input equivalent can be calculated. Based on the energy equivalent of the inputs and output (Table 2), energy ratio (energy use efficiency) and energy productivity were calculated according to Singh *et al*. (1998) and Mandal *et al.* (2002) , as follows:

Energy use efficiency = Energy output (MJha^{-1}) /Energy input (MJha^{-1}) (3)

Energy productivity = Pineapples output (kgha^{-1}) /Energy input (MJha^{-1}) (4)

Table 2
Energy equivalents for different inputs and outputs in agricultural production

	Unit	Energy equivalent (MJ unit^{-1})	Reference
Input			
1) Labour	h	1.96	Safa and Tabatabaeerfar (2002)
2) Machinery			
Tractor 50 hp	kg	109.00	Pimentel (1992)
Petrol engine, 5hp	kg	109.00	Pimentel (1992)
High pressure sprayer	kg	109.00	Pimentel (1992)
3) Fertiliser			
Nitrogen (N)	kg	61.53	Pimentel and Patzek (2005)
Phosphorus (P_2O_5)	kg	12.56	Pimentel and Patzek (2005)
Potassium (K_2O)	kg	6.70	Pimentel and Patzek (2005)
4) Agrochemicals			
Hydrated lime	kg	1.17	Pimentel and Patzek (2005)
Micronutrient*	kg	20.90	Anon (2004)
Ethrel	kg	255.00	Anon (2004)
Paraquat	kg	459.00	Anon (2004)
Glyphosate	kg	453.00	Anon (2004)
5) Fuel			
Diesel	l	56.31	Safa and Tabatabaeerfar (2002)
Petrol	l	46.30	Safa and Tabatabaeerfar (2002)
6) Suckers	kg	1.90	Ricaud (1980)
Output			
7) Fruits	kg	1.90	Singh and Mittal (1992)

Finally, the energy input was divided into direct, indirect, renewable and non-renewable forms. The indirect energy includes the chemical and farm fertilisers, seeds and machinery. The direct energy includes human labour and fuel. The non-renewable energy sources include fuel, fertiliser, pesticides and machinery, while the renewable energy sources include human labour and seeds.

RESULTS AND DISCUSSION

Operational energy consumption based on field operations

The operational energy consumption in the pineapple production system was distributed according to the following field operations: land preparation, planting, fertilising, hormone spraying, weeding, crop protection and harvesting. As shown in Table 3, the average operational energy consumption for fertilising of 16264.33 $MJha^{-1}$ was the highest, which accounted for about 54.61% of the computed total operational energy consumption of 29780.91 $MJha^{-1}$, followed by planting of 6512.03 $MJha^{-1}$ (21.87%), land preparation of 4056.18 $MJha^{-1}$ (13.62%), hormone spraying of 1371.74 $MJha^{-1}$ (4.61%) and harvesting of 1170.73 $MJha^{-1}$ (3.39%) of the total energy. Nonetheless, weeding and crop protection did not make any significant contribution to the operational energy consumption. The high operational energy for fertilising operation observed in the study was due to the fact that the fertilisers (N, P, K) incurred a high energy equivalent in the process, especially nitrogen (N). In this study area, most of the field operations were done manually. The involvement of machinery in the field operations was only for spraying activities. In Malaysia, the use of machinery for pineapples is still very low due to some circumstances like lacking the financial capability, uneconomical size of planting areas for mechanisation and problematic characteristics of peat soil. These are among the reasons for the continuous reliance on human labour in the plantation. As shown in Table 4, the planting operation was claimed to be sustaining the highest labour input with energy equivalent to 343.43$MJha^{-1}$, followed by weeding, crop protection and harvesting. As mentioned earlier, all these operations were done manually.

Table 3
Distribution of operational energy consumption by field operations

Field Operation	Energy used (MJ ha-1)	Portion (%)
Land preparation	4056.18	13.62
Planting	6512.03	21.87
Fertilising	16264.33	54.61
Hormone spraying	1371.74	4.61
Weeding	236.55	0.76
Crop protection	169.34	0.57
Harvesting	1170.73	3.39
Total	29780.91	100

Total energy consumption based on energy sources

The allocation of inputs and their energy equivalences used in the production of pineapples are shown in Table 4. The highest share of input equivalent energy is indicated by the fertiliser usage which accounted about 45.65% of the total equivalent energy in the pineapple production. In specific, the fertiliser used comprised of 79.4 kg of nitrogen, 19.20 kg of phosphorus and 56.40 kg of potassium. The second highest equivalent energy used in the production of pineapples was the fuel consumption, which was about 20.22% of the total equivalent energy. These were followed by other inputs such as planting material or sucker (17.33%), chemical application (12.76%), human labour (3.34%) and machinery (0.69%). Fertilisers and fuel were instigated as the highest energy simply because the energy equivalents for these two inputs were also very high. For fertiliser, nitrogen energy equivalent was 61.53 MJ kg^{-1}, whereas for fuel, diesel's energy equivalent was 56.31 MJ kg^{-1} and petrol's energy equivalent was 46.30 MJ kg^{-1}. Even though chemicals like flowering hormone also have a high energy equivalent (255 MJ kg^{-1}), the small quantity of hormone used in the cultivation has caused it to not giving any significant increment to the input. As mentioned earlier on, human labour is the backbone in the process of pineapple production since almost all of the field operations are done manually. However, as the calculation goes on, the low energy equivalent for labour (1.90 MJ h^{-1}) is simply because of its small contribution to the total equivalent energy.

Table 4
Allocation of physical inputs used in pineapple production

Input	Unit	Amount of input used per hectare	Energy equivalent (MJunit^{-1})	Energy equivalent (MJha^{-1})	Portion (%)
Labor (h)					3.34
Land preparation	h	13.34	1.96	26.13	
Planting	h	175.22	1.96	343.43	
Weeding	h	120.68	1.96	236.55	
Fertilizing	h	25.61	1.96	50.19	
Spraying hormone	h	2.91	1.96	5.71	
Crop protection	h	86.40	1.96	169.34	
Harvesting	h	83.88	1.96	164.40	
Machinery(kg)					*0.69*
Tractor, 50 hp	kg	4520.1	109	205.28[a]	
Petrol engine, 5 hp	kg	37.05	109	0.49[a]	
High pressure sprayer	kg	24.7	109	0.32[a]	
Fertiliser (kg)					*45.65*
Nitrogen (N)	kg	196.12	61.53	12067.14	
Phosphorus (P_2O_5)	kg	47.42	12.56	595.64	
Potassium (K_2O)	kg	139.31	6.70	933.36	

Table 2 (*continue*)

Input	Unit	Amount of input used per hectare	Energy equivalent (MJunit^{-1})	Energy equivalent (MJha^{-1})	Portion (%)
Agrochemicals (kg)					*12.76*
Hydrated lime	kg	50.00	1.17	144.50	
Micronutrient[b]	kg	7.50	20.90	387.17	
Ethrel	kg	0.48	255.00	302.33	
Paraquat	kg	0.84	459.00	952.33	
Glyphosate	kg	1.80	453.00	2014.04	
Fuel (L)					*20.22*
Diesel	l	41.64	56.31	5791.53	
Petrol	l	2.00	46.30	228.72	
Suckers(kg)	*kg*	*1100.00*	*1.90*	*5162.30*	*17.33*
Total energy input (MJ ha^{-1})				29780.91	100
Yield of pineapple (kg ha^{-1})		55749.78	1.90	105924.59	
Ratio of energy output/input				3.56	
Energy productivity (kg MJ^{-1})				1.87	

[a] Based on calculation using equation [2] and the average usage of machinery is 1.2 hours.
[b] Ferrous sulfate, copper sulfate, zinc sulfate

In specific, the energy equivalent used for labour, machinery, fertiliser, agrochemical, fuel (including the plant material) was about 29780.91 MJ ha^{-1} for 14 months of pineapple cultivation or equivalent to 2127.21 MJ ha^{-1} per month. The monthly input of 2127.21 MJ ha^{-1}energy needed for the pineapple production at KOSAS Bhd. plantation was 47.29% lower compared to the total of 4035.65 MJ.ha^{-1} energy per month required by the pineapple plantations in Hawaii (Duke, 1983). Duke (1983) reported that the pineapple production in Hawaii requires monthly inputs of 60.71 MJ.ha^{-1} for manual labour, 205.15 MJ.ha^{-1} for machines, 2271.76 MJ.ha^{-1} for fuel, 1418.91 MJ.ha^{-1} for fertilisers and 79.13 MJ.ha^{-1} for pesticides. The different soil characteristics and nature of works have caused pineapple production in KOSAS Bhd plantation requires lesser energy inputs than that of the plantations in Hawaii. As mentioned earlier, in KOSAS Bhd. plantation, pineapple is cultivated on peat soil area, while in Hawaii, pineapple is mainly grown silt loams, silty clay loams and silty clay (Hepton, 2003). Problematic characteristics of peat soil, with an extreme low bearing capacity, have limited the use of heavy machinery in KOSAS Bhd. plantation. Thus, fuel usage is less as a result of limited machinery use. Besides, KOSAS Bhd. plantation also adopted no-tillage method and minimum fertiliser input for growing pineapples due to higher fertility of prepared peat soil in this plantation. These conditions have enable KOSAS Bhd. plantation to save more energy inputs in pineapple production.

Energy use efficiency

Based on the yield per hectare, the total energy output in pineapple cultivation in KOSAS Bhd. plantation was 55749.78 kg ha^{-1}. The energy equivalent to produce the yield is 29780.91 $MJha^{-1}$. Therefore, the energy productivity indicates that the product amount obtained from the unit area in return for the used energy amount is 1.87 MJ kg^{-1} (Table 4). In other words, for 1.87 kg of produce, 1 MJ of energy is used in the farm. The energy use efficiency is determined as the ratio of output energy to input energy. This in line with the statement by the International Energy Agency (2016), who states that something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. Thus, it is assumed that if the energy ratio is greater than 1, the production system is therefore gaining energy; otherwise, it is losing energy. The energy use efficiency in the pineapple production was 3.56 (Table 4). It is shown that the pineapple cultivation by KOSAS Bhd. earned at least 3.56 times of the energy inputs given into the production process. This can be considered as a very efficient use of inputs. Thus, the calculated energy use efficiency of the pineapple production in the study area is more efficient as compared to the respective output/input ratio of 1.10 for apple production in Turkey (Nuray, 2009), 1.24, 1.31 and 3.37 for apricot production (Gezer et al., 2003; Esengun et al., 2007). Moreover, it is also higher than the ratio of 1.25, 1.06 and 1.17 for the production of orange, lemon and mandarin, respectively (Ozkan et al., 2004), as well as of rice production range, i.e. from 1.03 to 1.76, in US (Duke, 1983). However, the calculated energy use efficiency of pineapple production was lower compared to the energy use efficiency in the rice cultivation in Malaysia, with a ratio of 8.86 (Bockari et al., 2005). Nonetheless, the irrigation input was not included in their study.

Energy of direct, indirect, renewable and non-renewable

Finally, the energy input in the production of pineapple was divided into direct and indirect, and also renewable and non-renewable forms as presented in Figures 1 and 2. Direct energy is the energy that is invested physically in the farm like labour, fuel and electricity, while indirect energy is the energy that comes from the manufacturer of the inputs like fertilisers, agrochemicals and machinery. The direct energy was 23.56% lower than the indirect energy resource, which was 76.44% of the total energy input. The same thing also goes to the portion of renewable and non-renewable energy, where it was fairly different from each other. The portion of renewable energy inputs within the total energy was 20.68%, which is considered as very low as compared to the overall portion of energy from renewable resources in Iceland (72%), Norway (64%), New Zealand (32%), Chile (29%), Canada (24%) and Switzerland (24%) (Eurostat, 2016).

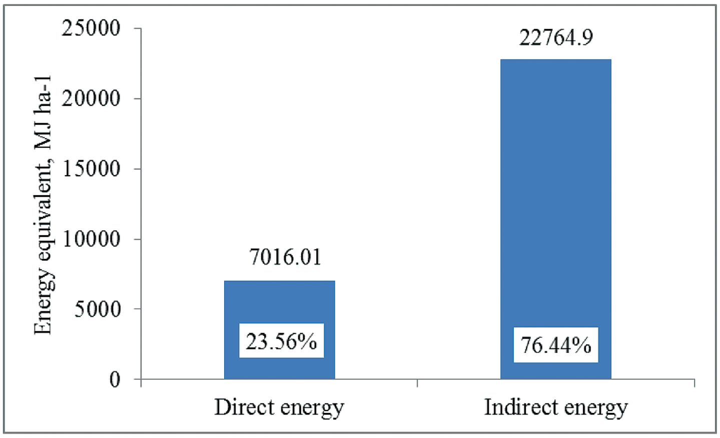

Figure 1. Distribution of direct and indirect energy inputs in the production of pineapples

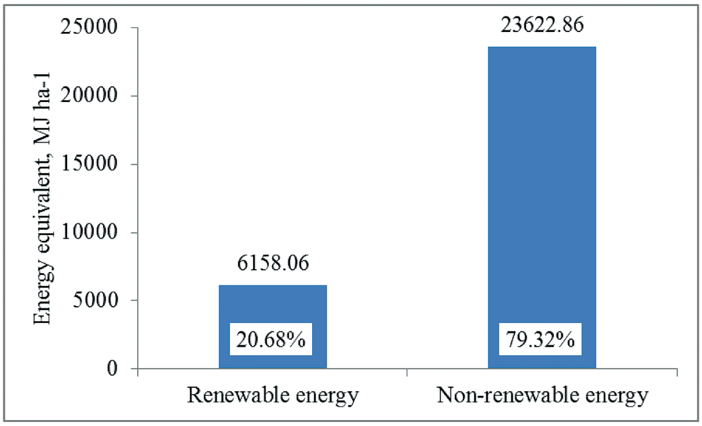

Figure 2. Distribution of renewable and non-renewable energy inputs in the production of pineapples

Generally, the findings of this study are very useful to enrich the database of energy consumption in the production of pineapples, particularly in the production of pineapples in peat soil areas, in which about 90% of the total pineapples planted areas in Malaysia are on peat soil (Chan, 2000). Similar findings published by Duke (1983) from past research conducted in Hawaiian pineapple plantations are limited to pineapple cultivation on the soil in Hawaii only, which is characterised mostly by silt loams, silty clay loams and silty clay (Hepton, 2003).

CONCLUSION

The distribution of energy consumption in pineapple production in Malaysia has successfully been audited and analysed through a case study carried out at a pineapple plantation under KOSAS Bhd. located at Kg. Kundang in Selangor, Malaysia. The calculated energy used for the pineapple production in KOSAS Bhd. was 29780.91 MJ ha^{-1}. A very large portion of this energy (54.61%) was provided for fertilising operation, where compound NPK fertiliser, urea and other micronutrient fertilisers supplied about 45.65% of the total production energy. The ratio of energy output/input was 3.56, whereby the input is highly and effectively used at this pineapple plantation. It is essential to use the resources effectively for a sustainable agricultural production. Basically, a sustainable agriculture production requires sustainable supply of energy resources. Even though labour input has a small portion in energy consumption at the pineapple plantation, the use of appropriate machinery in cultivation practices in Malaysia is recommended as an alternative to reduce human drudgery and to optimise the capability of plantation to do work efficiently and also to offset the labour shortage problem.

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